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(54) Polypropylene multifilament warp knitted mesh and its use in surgery

Kettengewirktes Multifilnetzwerk aus Polypropylen und seine Verwendung in der Chirurgie

Treillis de multifilament de polypropylène tricoté en chaîne et son utilisation en chirurgie

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EP-A- 0 101 650 US-A- 4 769 038

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Description.**BACKGROUND OF THE INVENTION**

5 This invention relates to a textile material and, in particular, to a nonabsorbable surgical mesh of warp knit construction fabricated from a polypropylene multifilament yarn.

Knitted and woven fabrics constructed from a variety of synthetic fibers and the use of the fabrics in surgical repair are known from, among others, U.S. Patent Nos. 3,054,406; 3,124,136; 4,193,137; 4,347,847; 4,452,245; 4,520,821; 4,633,873; 4,652,264; 4,655,221; 4,838,884; 5,002,551; and, European Patent Application No. 334,046.

10 Hernia repairs are among the more common surgical operations which employ a mesh fabric prosthesis. A mesh constructed from polypropylene monofilament, while it induces a good fibroblastic response ensuring its prompt fixation and integration with tissue at the surgical repair site, is considered to be too stiff for some types of hernioplasties, e.g., giant prosthetic reinforcement of the visceral sac (GPRVS). While a warp knitted surgical mesh constructed from a non-absorbable polyester multifilament yarn (e.g., Mersilene of Ethicon, Inc.) has been indicated to be a particularly desirable prosthesis for a GPRVS procedure due to its suppleness and elasticity (Wantz, "Atlas of Hernia Surgery", Raven Press, 1991, p. 102), were it not for the aforementioned stiffness associated with a polypropylene monofilament mesh, the later would likely be the material of choice due to its greater strength and chemical inertness.

SUMMARY OF THE INVENTION

20 It is an object of the present invention to provide a surgical mesh fabricated from polypropylene multifilament yarn which exhibits an appreciably greater flexibility than a surgical mesh constructed from polypropylene monofilament.

It is another object of the invention to provide a polypropylene multifilament warp knitted surgical mesh exhibiting a flexibility which is at least comparable to that of a nonabsorbable polyester multifilament surgical mesh of similar construction but possessing greater mechanical strength than the latter.

25 It is yet another object of the invention to provide a surgical mesh with a color pattern which facilitates the orientation and/or installation of the mesh at a surgical repair site.

Another specific object of the invention is the provision of a thermoplastic surgical mesh which is cut to size with an ultrasonic slitter.

30 Still another specific object of the invention is the provision of a surgical mesh coated on one side with a material that prevents or minimizes organ adhesions.

In keeping with these and other objects of the invention, there is provided a warp knitted surgical mesh fabricated from polypropylene multifilament yarn.

35 The foregoing mesh is considerably more flexible than any of the known surgical mesh materials constructed from monofilament. Thus, e.g., the mesh of this invention can be more easily passed through a trocar and into a body cavity. The greater flexibility of the mesh makes it more maneuverable and easier to be installed at the desired surgical site than a monofilament mesh of otherwise similar construction. Compared to a nonbioabsorbable surgical mesh knitted from polyester multifilament yarn, the polypropylene multifilament mesh of this invention possesses much greater strength but at no loss of flexibility and suppleness.

40 The mesh of this invention finds application in a number of surgical procedures including the repair of hernias, anatomical defects of the abdominal wall, diaphragm, and chest wall, correction of defects in the genitourinary system, repair of traumatically damaged organs such as the spleen, liver or kidney, and so forth.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

45 The surgical mesh of this invention is fabricated from a yarn formed from a polypropylene resin (isotactic index of at least about 90), preferably one which is already accepted for use as a suture material, e.g., a polypropylene resin having a melt flow index in g/10 min (ASTM D 1231-82) of from about 2 to about 6, preferably from about 2.1 to about 5.0 and most preferably from about 2.5 to about 4.6.

50 Known and conventional apparatus and procedures can be used for the production of polypropylene multifilament yarns from which the mesh of this invention is constructed. Properties of the individual polypropylene filaments and the yarns manufactured therefrom are advantageously as set forth in Table I below:

TABLE I

PROPERTIES OF MONOFILAMENTS AND AND YARNS CONSTRUCTED THERE- FROM			
	Broad Range	Preferred Range	Most Preferred Range
Denier per Filament	0.5-6	1-4	2-3
Filaments per Yarn	10-60	20-40	25-35
Denier per Yarn	at least 10	40-80	50-70

During the spinning process, after the individual polypropylene filaments have been brought together to provide the yarn, it is conventional practice to apply a spin finish to the yarn. The spin finish typically contains lubricant, antistatic and adhesive components to hold the yarn together and improve its processability, e.g., drawability. One spin finish composition which is known to provide generally good results is Luroi 1187 (Goulston Inc., 700 N. Johnson Street, Monroe, NC 28110) which can be applied to the yarn from solution prepared with a suitable solvent, e.g., as a 5-35 weight percent solution in isopropyl alcohol.

Following spinning, the multifilament yarn is ordinarily subjected to further mechanical processing, e.g., twisting, air entanglement, etc., in order to further enhance its processability. Thus, e.g., the yarn can be ring twisted at a rate of from about 1 to about 5 turns per inch (25.4 mm) or air entangled at a level of at least about 50 nodes per meter prior to being knitted into mesh.

In a preferred melt spinning process for obtaining yarn to be knitted into the surgical mesh of this invention, the isotactic polypropylene resin, melt spinning equipment and ranges of operating conditions set forth below in Table II can be advantageously employed:

**TABLE II: MELT SPINNING OF POLYPROPYLENE
MULTIFILAMENT YARNS**

A. Polypropylene Resin

The preferred polypropylene resin is a surgical suture grade resin having an isotactic index of about 95 or greater and a melt flow rate of from about 2.5 to about 4.6.

b. Melt Spinning Apparatus and Operating Conditions

Apparatus Component Operating Parameter	Range of Operating Condition
Extruder barrel temp., zone 1 °C	230-250
Extruder barrel temp., zone 2 °C	230-270
Extruder barrel temp., zone 3 °C	230-270
Extruder barrel pressure, (psi)Pa	(1000-2000) 6.9-10 ⁶
Extruder barrel melt temp., °C	230-275 13.8-10 ⁶
Pump size, cc per rev	.16-.584
Pump rpm	25-35 for size .16 pump 6-10 for size .584 pump
Pump temp., °C	220-250
Pump pressure, (psi)Pa	(400-1000) 2.7-10 ⁶
Pump melt temp., °C	215-255 6.9-10 ⁶
Block temp., °C	220-250
Clamp temp., °C	220-250
Adapter temp., °C	220-250
Candle filter, screen, microns	10-100
No. of spinneret orifices	10-200
Diameter of spinneret orifices (.001 in)mm	(5-30) 0.127-0.762
Spinneret temp., °C	220-250
Spinneret pressure, (psi)Pa	(400-1500) 2.7-10 ⁶
Spinneret melt temp., °C	215-255 10.3-10 ⁶
cc/hr output, per spinneret orifice	5-20
First pair of godets, °C	40-90
First pair of godets, mpm	100-300
Second pair of godets, °C	70-130
Second pair of godets, mpm	300-1000
Draw (stretch) ratio	2-4
Third pair of godets, °C	ambient
Third pair of godets, mpm	250-1000
Shrinkage (relaxation), percent	5-15

c. Properties of Individual Filaments and Polypropylene Yarns Obtained Therefrom

Property	Range of Property
Denier per Filament	.3-20
Filaments per Yarn	10-200
Denier per Yarn	3-300

The surgical mesh of this invention can be fabricated from these and similar multifilament polypropylene yarns employing known and conventional warp knitting apparatus and techniques, e.g., the tricot and Raschel knitting machines and procedures described in "Warp Knitting Production" by Dr. S. Raz, Melland Textilberichte GmbH, Rohr-

bacher Str. 76, D-6900 Heidelberg, Germany (1987), the contents of which are incorporated by reference herein. As is well known in the art of warp knitting, the number of courses and wales per inch (25.4 mm) in a knitted material is affected by a number of machine operating variables such as the rate at which the fabric is drawn away from the needles, the number of needles per inch (25.4 mm), the amount of tension applied to the warp yarns and other variables after the fabric leaves the machine, e.g., the heat setting conditions.

The structure of the knitted mesh of this invention can be defined for any given yarn in terms of the number of courses and wales per inch (25.4 mm) and the knit design for which there can be a great number of variations. Advantageously, the polypropylene multifilament yarns of Table II can be warp knitted, preferably tricot knitted on a 2 bar set-up, to provide surgical meshes possessing the structural characteristics set forth in Table III as follows:

TABLE III

STRUCTURAL CHARACTERISTICS OF SURGICAL MESHES			
	Broad Range	Preferred Range	Most Preferred Range
Courses per Inch (25.4mm)	20-80	25-60	30-50
Wales per Inch (25.4mm)	12-40	18-34	20-24

Following knitting, the mesh is cleaned to remove the spin finish and thereafter heat set to stabilize the fabric. For the latter operation, the mesh can be secured to a tenter frame which maintains the mesh at a predetermined width, the frame then being passed through an elongate heating zone at a temperature of from about 120 to about 180°C, preferably at a temperature of from about 120 to about 150°C, at a rate providing a dwell time of from about 10 to about 55 seconds and preferably from about 20 to about 50 seconds. On a smaller scale, the mesh can be mounted upon a stationary frame which is then placed in an oven for about 5 to about 12 minutes at from about 125 to about 140°C. Following heat setting, the mesh is cut to size, packaged and sterilized.

The mesh can be cut to any desired configuration, e.g., a square or rectangular shape, of appropriate dimensions. Two suitable configurations are a square of 101.6mm (4 inches) and a rectangle measuring 228.6mm (9 inches) by 355.6mm (14 inches). In cutting the mesh to size, it has been found advantageous to employ an ultrasonic slitter or cutter, various types of which are commercially available. Unlike the result one obtains when cutting with a blade, i.e., frayed yarn ends, or when the yarn ends are heat-sealed, i.e., bead-like formations, cutting the mesh to size with an ultrasonic cutter avoids both frayed and beaded ends.

The polypropylene multifilament warp knitted mesh of this invention possesses a ball burst strength (ASTM D 3787-80A) of at least about 50 kg, preferably at least about 50 kg and most preferably at least about 80 kg. Even at only 50 kg ball burst strength, the mesh of this invention is considerably stronger, e.g., up to 100 percent stronger, than a non-absorbable polyester multifilament warp knitted mesh of otherwise comparable construction.

For some applications, particularly those involving laparoscopic procedures, it may be desirable to partially stiffen the mesh so that the mesh can be rolled up for easy passage through a trocar and into a body cavity and once inside the body, spring back to its previous flattened condition. One way of accomplishing this partial stiffening effect is to coat the mesh with a polymer such as poly(hydroxymethyl methacrylate). The amount of polymer applied to the mesh to achieve a particular stiffening effect can, of course, be determined employing simple and routine experimentation. Stiffening can also be achieved by heating the mesh at a temperature which is higher and/or for a period of time which is longer than the aforementioned heat setting conditions. Thus, heating at from about 160 to about 180°C for from about 30 minutes to about 2 hours will cause the mesh to stiffen.

It can also be advantageous to provide the surgical mesh of this invention with a clearly visible color pattern, e.g., in the form of a grid of two differently colored yarns such as dark blue and light blue, dark blue or light blue and clear or natural, etc., as such a pattern will tend to facilitate the proper orientation and/or installation of the mesh at the surgical repair site. The mesh can contain yarn of one color in the machine direction, yarn of the other color being incorporated into the mesh fabric after knitting. In the case where the mesh is manufactured on a weft insertion warp knitter, both the knitting and the insertion of the weft can be accomplished in a single operation.

The following example is illustrative of the surgical mesh of this invention and its fabrication.

EXAMPLE

The surgical mesh of this invention was manufactured from a 96 percent isotactic polypropylene having a melt flow index of about 3.3 g/10 min, a weight average molecular weight of 283,000 and a number average weight of 61,000 as reported by the supplier (Resin F040A Natural of Aristech Chemical Corporation, Pittsburgh, PA).

The conditions of melt spinning the polypropylene multifilament yarn, warp knitting the yarn to provide the surgical

mesh and the properties of the mesh and its heat setting conditions are set forth in Table IV below:

TABLE IV: SURGICAL MESH MANUFACTURING CONDITIONS

A. Melt Spinning Apparatus and Operating Conditions

Apparatus Component, Operating Parameter Operating Condition

Extruder barrel temp., zone 1 °C	240
Extruder barrel temp., zone 2 °C	260
Extruder barrel temp., zone 3 °C	260
Extruder barrel pressure, (psi)Pa	(1500) 10.3-10 ⁶
Extruder barrel melt temp., °C	260
Pump size, cc per rev	0.16
Pump rpm	32
Pump temp., °C	240
Pump pressure, (psi)Pa	(500-750) 3.4-10 ⁶
Pump melt temp., °C	240 5.2-10 ⁶
Block temp., °C	240
Clamp temp., °C	240
Adapter temp., °C	240
Candle filter, screen, microns	40
No. of spinneret orifices	30
Diameter of spinneret orifices (.001 in)mm	(10) 0.254
Spinneret temp., °C	240
Spinneret pressure, (psi)Pa	(400-800) 2.7-10 ⁶
Spinneret melt temp., °C	240 5.5-10 ⁶
Spinneret melt temp., °C	215-255 10.3-10 ⁶
cc/hr output, per spinneret orifice	10.2
First pair of godets, °C	65
First pair of godets, mpm	160
Second pair of godets, °C	90
Second pair of godets, mpm	510
Draw (stretch) ratio	2.9
Third pair of godets, °C	ambient
Third pair of godets, mpm	465
Shrinkage (relaxation), percent	9
Spin Finish	35 wt% isopropyl alcohol solution of Lurol 1187, as needed

B. Properties of Polypropylene Multifilament Yarn

Denier per Filament: 2
 Filaments per Yarn: 30
 Denier per Yarn: 60

C. Tricot Knitting Conditions

Knitting Machine: 20 gauge (20 needle)
 2-bar tricot knitter
 (Mayer Textile Machine
 Corporation, Clifton, NJ)

Courses per Inch (25.4mm) 40

Wales per Inch (25.4mm) 22

Knit Design:	<u>Back Bar</u>	<u>Front Bar</u>
	1/0	0/1
	4/5	1/0

D. Properties of the Surgical Mesh

Fabric Width: 1.2 meters (48 inches)

Fabric Weight: 2.5-2.8 oz./sq. yd.

Ball Burst Strength: .58 kg

The mesh was heat set by being clamped to a frame and placed in an oven heated to 130° for 10 minutes.
 Within their scope, the claims which follow define embodiments of the invention additional to those specifically described above.

Claims

1. A warp knitted surgical mesh fabricated from polypropylene multifilament yarn.
2. A mesh as claimed in claim 1 wherein the polypropylene is an isotactic polypropylene resin having a melt flow index, g/10 min, of from 2 to 6.
3. A mesh as claimed in claim 2 wherein the polypropylene is an isotactic polypropylene resin having a melt flow index, g/10 min, of from 2.1 to 5.0.
4. A mesh as claimed in claim 2 wherein the polypropylene is an isotactic polypropylene resin having a melt flow index, g/10 min, of from 2.5 to 4.0.
5. A mesh as claimed in any one of the preceding claims wherein the yarn is made from filaments of from 0.5 to 6

denier, the yarn is constructed with from 60 to 10 filaments and the yarn possesses a denier of at least 10.

6. A mesh as claimed in claim 5 wherein the yarn is made from filaments of from 1 to 4 denier, the yarn is constructed with from 20 to 40 filaments and the yarn possesses a denier of from 40 to 80.
7. A mesh as claimed in claim 6 wherein the yarn is made from filaments of from 2 to 3 denier, the yarn is constructed with from 25 to 35 filaments and the yarn possesses a denier of from 50 to 70.
8. A mesh as claimed in any one of the preceding claims wherein the mesh possesses from 20 to 80 courses per inch (25.4 mm) and from 12 to 40 wales per inch (25.4 mm).
9. A mesh as claimed in claim 8 wherein the mesh possesses from 25 to 60 courses per inch (25.4 mm) and from 18 to 32 - 34 wales per inch (25.4 mm).
10. A mesh as claimed in any one of the preceding claims exhibiting a colour pattern to facilitate its orientation and/or installation at the surgical repair site.
11. A mesh as claimed in any one of the preceding claims and heat set or heat stiffened.
12. A mesh as claimed in any one of the preceding claims and coated for enhanced stiffness.
13. A mesh as claimed in claim 12, the coating comprising poly(hydroxymethacrylate).
14. A mesh as claimed in any one of the preceding claims, cut to size and with the cut ends of the yarns being sealed but unbeaded.
15. A method of making surgical mesh wherein a polypropylene multifilament yarn is produced by a process which comprises melt spinning an isotactic polypropylene having a melt flow index, g/10 min, of from about 2 to about 6 employing an extruder equipped with a spinneret and downstream of the extruder a draw frame possessing three pairs of godets, the extruder being operated in one or more zones thereof at a temperature of about 230 to about 270°C, the pressure of the extruder being from about $6.9 \cdot 10^5$ (1000) to about $13.8 \cdot 10^6$ Pa (2000 psi), the temperature of the spinneret being from about 220 to about 250°C, the first pair of godets being operated at a temperature of from about 40 to about 90°C and an rpm of from about 100 to 300, the second godet being operated at a temperature of from about 70 to about 130°C and an rpm of from about 300 to about 1000 and the third godet being operated at ambient temperature and an rpm of from about 250 to about 1000, the draw ratio of the yarn being from about 2 to about 4 and the shrinkage of the yarn being from about 5 to about 15 percent.
16. A method of making surgical mesh characterised in that the mesh is as claimed in claim 1.

Patentansprüche

1. Kettengewirktes chirurgisches Gewebe, das aus einem Multifaser-Polypropylengarn hergestellt ist.
2. Gewebe gemäß Anspruch 1, wobei das Polypropylen ein isotaktisches Polypropylenharz mit einem Schmelzindex, g/10 min, von 2 bis 6 ist.
3. Gewebe gemäß Anspruch 2, wobei das Polypropylen ein isotaktisches Polypropylenharz mit einem Schmelzindex, g/10 min, von 2,1 bis 5 ist.
4. Gewebe gemäß Anspruch 2, wobei das Polypropylen ein isotaktisches Polypropylenharz mit einem Schmelzindex, g/10 min, von 2,5 bis 4 ist.
5. Gewebe gemäß einem der vorhergehenden Ansprüche, wobei der Garn aus Fasern von 0,5 bis 6 Denier hergestellt ist und der Garn aus 60 bis 10 Fasern aufgebaut ist und der Garn ein Denier von zumindest 10 besitzt.
6. Gewebe gemäß Anspruch 5, wobei der Garn aus Fasern von 1 bis 4 Denier hergestellt ist, der Garn aus 20 bis 40 Fasern aufgebaut ist und der Garn einen Denier von 40 bis 80 besitzt.

7. Gewebe gemäß Anspruch 6, wobei der Garn aus Fasern von 2 bis 3 Denier hergestellt ist, der Garn aus 25 bis 35 Fasern aufgebaut ist und der Garn einen Denier von 50 bis 70 besitzt.
- 5 8. Gewebe gemäß einem der vorhergehenden Ansprüche, wobei das Gewebe von 20 bis 80 Maschenreihen pro Inch (25,4 mm) und von 12 bis 40 Längsreihen pro Inch (25,4 mm) besitzt.
9. Gewebe gemäß Anspruch 8, wobei das Gewebe von 25 bis 60 Maschenreihen pro Inch (25,4 mm) und von 18 bis 32 bis 34 Längsreihen pro Inch (25,4 mm) besitzt.
- 10 10. Gewebe gemäß einem der vorhergehenden Ansprüche, das ein Farbmuster aufweist, um seine Ausrichtung und/oder Anbringung am chirurgischen Operationsort zu erleichtern.
11. Gewebe gemäß einem der vorhergehenden Ansprüche, und thermofixiert oder wärmeausgesteift.
- 15 12. Gewebe gemäß einem der vorhergehenden Ansprüche und für eine erhöhte Steifigkeit beschichtet.
13. Gewebe gemäß Anspruch 12, wobei die Beschichtung Poly(hydroxymethacrylat) umfaßt.
14. Gewebe gemäß einem der vorhergehenden Ansprüche, das zugeschnitten ist und wobei die geschnittenen Enden der Garne versiegelt aber nicht wulstartig sind.
- 20 15. Verfahren zum Herstellen eines chirurgischen Gewebes, wobei ein Polypropylen-Multifasergarn durch ein Verfahren hergestellt wird, das umfaßt das Schmelzspinnen eines isotaktischen Polypropylens mit einem Schmelzindex, g/10 min, von etwa 2 bis 6 unter Verwendung eines Extruders, der mit einer Spinnvorrichtung ausgestattet ist und stromabwärts des Extruders einem Ziehrahmen, der drei Paare von Zugrollen besitzt, wobei der Extruder in einer oder mehreren Zonen desselben bei einer Temperatur von etwa 230 bis etwa 270 °C betrieben wird und der Druck des Extruders von etwa $6,9 \cdot 10^6$ (1000) bis etwa $13,8 \cdot 10^6$ Pa (2000 psi) ist, wobei die Temperatur der Spinnvorrichtung von etwa 220 bis etwa 250 °C ist, das erste Paar von Zugrollen bei einer Temperatur von etwa 40 bis etwa 90 °C und einem m/min von etwa 100 bis 300 betrieben werden, die zweite Zugrolle bei einer Temperatur von etwa 70 bis etwa 130 °C und einer m/min von etwa 300 bis etwa 1000 betrieben wird und die dritte Zugrolle bei Umgebungstemperatur und einer m/min von etwa 250 bis etwa 1000 betrieben wird, wobei das Ziehverhältnis des Garnes von etwa 2 bis etwa 4 und die Schrumpfung des Garnes von etwa 5 bis etwa 15 Prozent ist.
- 30 16. Verfahren zum Herstellen von chirurgischen Gewebe, dadurch gekennzeichnet, daß das Gewebe wie in Anspruch 1 beansprucht ist.
- 35

Revendications

- 40 1. Treillis chirurgical tricoté en chaîne fabriqué d'un fil multifilament de polypropylène.
2. Treillis selon la revendication 1 où le polypropylène est une résine de polypropylène isotactique ayant un indice d'écoulement en phase fondue, g/10 mn., de 2 à 6.
- 45 3. Treillis selon la revendication 2 où le polypropylène est une résine de polypropylène isotactique ayant un indice d'écoulement en phase fondue, g/10 mn., de 2,1 à 5,0.
4. Treillis selon la revendication 2 où le polypropylène est une résine de polypropylène isotactique ayant un indice d'écoulement en phase fondue, g/10 mn., de 2,5 à 4,0.
- 50 5. Treillis selon l'une quelconque des revendications précédentes, où le fil est fait de filaments de 0,5 à 6 deniers, le fil est construit de 60 à 10 filaments et le fil possède un denier d'au moins 10.
6. Treillis selon la revendication 5, où le fil est fait de filaments de 1 à 4 deniers, le fil est construit de 20 à 40 filaments et le fil possède un denier de 40 à 80.
- 55 7. Treillis selon la revendication 6, où le fil est fait de filaments de 2 à 3 deniers, le fil est construit de 25 à 35 filaments et le fil possède un denier de 50 à 70.

8. Treillis selon l'une quelconque des revendications précédentes, où le treillis possède 20 à 80 rangs par pouce (25,4 mm) et 12 à 40 côtes par pouce (25,4 mm).
9. Treillis selon la revendication 8, où le treillis possède 25 à 60 rangs par pouce (25,4 mm) et 18 à 32-34 côtes par pouce (25,4 mm).
10. Treillis selon l'une quelconque des revendications précédentes présentant un motif de couleur pour faciliter son orientation et/ou son installation au site de réparation chirurgicale.
11. Treillis selon l'une quelconque des revendications précédentes qui est pris à la chaleur ou raidi à la chaleur.
12. Treillis selon l'une quelconque des revendications précédentes et enduit pour améliorer sa raideur.
13. Treillis selon la revendication 12, le revêtement comprenant du poly(hydroxyméthacrylate).
14. Treillis selon l'une quelconque des revendications précédentes coupé à la grandeur et avec les extrémités de coupe des fils qui sont scellées mais sans former de boules.
15. Méthode de fabrication d'un treillis chirurgical où un fil multifilament de polypropylène est produit par un procédé qui consiste à filer en phase fondue un polypropylène isotactique ayant un indice d'écoulement en phase fondue, g/10 mn., d'environ 2 à environ 6 en employant une extrudeuse équipée d'une filière et en aval de l'extrudeuse un cadre élargisseur possédant trois paires de godets, l'extrudeuse fonctionnant dans une ou plusieurs zones à une température d'environ 230 à environ 270°C, la pression de l'extrudeuse étant d'environ $6,9 \times 10^6$ (1000) à environ $13,8 \times 10^6$ Pa (2000 psi), la température de la filière étant comprise entre environ 220 et environ 250°C, la première paire de godets fonctionnant à une température d'environ 40 à environ 90°C et avec mpm d'environ 100 à 300, les deuxième godets fonctionnant à une température d'environ 70 à environ 130°C et mpm d'environ 300 à environ 1000 et le troisième godet fonctionnant à la température ambiante et avec mpm d'environ 250 à environ 1000, le rapport d'étrépage du fil étant compris entre environ 2 et environ 4 et le rétrécissement du fil étant compris entre environ 5 et environ 15 pour cent.
16. Méthode de production d'un treillis chirurgical caractérisé en ce que le treillis est tel que revendiqué à la revendication 1.